IN THE SPECIFICATION

Please insert the following paragraph after paragraph [0026].

Figure 1A depicts an exemplary alignment system according to an embodiment of the present invention;

Please insert the following paragraphs after paragraph [0045].

In one embodiment, the alignment system comprises two separate and identical alignment systems AS_1 and AS_2 which are arranged symmetrically relative to the optical axis AA' of the projection-lens system PL, as shown in FIG. 1A. The alignment system AS_1 is associated with the mask mark M_2 and the alignment system AS_2 with the mask mark M_1. Corresponding elements of the two alignment systems bear identical reference numerals, the reference numerals of the elements of the system AS_2 being primed to distinguish them from those of the system AS_1.

The construction of the system AS_1 and the manner in which the relative position of the mask mark M_2 and the substrate mark P_1 is determined by means of this system will now be described first.

The alignment system AS_1 comprises a radiation source 1, for example a helium-neon laser, which emits an alignment beam b. A beam splitter 2 reflects this beam to the substrate W. The beam splitter may comprise a semi-transparent mirror or a semi-transparent prism, but suitably comprises a polarisation-sensitive prism followed by a $\lambda/4$ plate 3, where λ is the wavelength of the beam b. The projection-lens system PL focuses the beam b to form a small radiation spot V of a diameter of the order of 1 mm onto the substrate W. This substrate reflects a part of the beam as the beam b_1 towards the mask M. The beam b_1 traverses the projection-lens system PL, which system images the radiation spot V on the mask. Before the substrate is mounted in the exposure apparatus it is so pre-aligned in a pre-alignment station coupled to the arrangement, for example a station as described in European Patent Application No. 0,164,165, that the radiation spot V is situated on the substrate mark P_1. This mark is then imaged onto the mask mark M_2 by the beam b_1. Allowing for the magnification

M of the projection-lens system, the dimension of the mask mark M_2 is adapted to that of the substrate mark P_1, so that in the case of a correct positioning of the two marks relative to each other the image of the mark P_1 coincides accurately with the mark M_2.

On its way towards and back from the substrate W the beam b, and the beam b_1 respectively, has twice traversed the $\lambda/4$ plate 3, the optic axis of this plate extending at an angle of 45° to the direction of polarization of the linearly polarized beam b issuing from the source 1. The beam b_1 traversing the $\lambda/4$ plate then has a direction of polarization which is rotated through 90° relative to the beam b, so that the beam b_1 is transmitted by the polarization separating prism 2. The use of the polarization separating prism in conjunction with the $\lambda/4$ plate has the advantage that the alignment beam can be coupled into the radiation path of the alignment system with a minimal loss of radiation.

The beam b_1 transmitted by the alignment mark M_2 is reflected by a prism 11 and is directed towards a radiation-sensitive detector 13, for example by another reflecting prism 12. This detector is, for example, a composite photodiode comprising, for example, four separate radiation-sensitive areas. The output signals of these detectors are a measure of the registration of the mark M_2 with the image of the substrate mark P_1. These signals can be processed electronically and may be employed to move the mask and the substrate relative to each other by means of drive systems, not shown, in such a way that the image of the mark P_1 coincides with the mark M_2. Thus, an automatic alignment arrangement is obtained. The signal from the detector 13 is amplified and processed in a phase-sensitive detection circuit 21, which also receives a signal V_B. The output signal S_A then constitutes the desired dynamical alignment signal.

A beam splitter 14, for example a semitransparent prism, may be arranged between the prism 11 and the detector 13 to split off a part of the beam b_1 so as to form a beam b_2. The split-off beam b_2 is incident on a television camera 17, which is coupled to a monitor, not shown, on which the alignment marks P_1 and M_2 are displayed for the operator of the exposure apparatus. The operator can then establish whether the two marks coincide or can move the substrate W by means of manipulators in order to make the marks coincide.

In a way similar to that described above for the marks M_2 and P_1 the marks M_1 and P_1 and the marks M_1 and P_2 can also be aligned relative to one another. For the two last-mentioned alignments the alignment system AS_2 is employed.

Before the substrate W is introduced into the exposure apparatus it has been pre-aligned coarsely, that is within an accuracy of some tens of μm, in a pre-alignment station in such a way that one of the alignment beams b or b' is incident on one of the substrate marks P_1 or P_2. It is possible to ensure that first the substrate mark P_1 is situated in the radiation path of the system AS_1, that is in the beam b. By means of the system AS_1 and by moving the substrate and the mask relative to each other in the X-direction and the Y-direction the marks P_1 and M_2 are aligned relative to one another.

The displacement of the substrate and the mask relative to each other is measured with a very accurate two-dimensional displacement system, for example the interferometer system described in U.S. Pat. No. 4,251,160. This system, which is represented schematically in FIG. 1 where it bears the reference IF, cooperates very closely with the alignment systems AS_1 and AS_2. As the instant at which the alignment system AS_1 ascertains that the marks P_1 and M_2 are aligned correctly, the interferometer system determines where the substrate mark P_1 is situated in the coordinate system defined by the interferometer system. The position of the image of the mask mark M_2 on the substrate is then known and hence the position in the X-direction and the Y-direction of the local image of the mask pattern C on the substrate.

Subsequently, the substrate mark P_1 is brought into the path of the beam b' and the alignment system AS_2 is employed to align this mark relative to the mask mark M_1. By means of the displacement measuring system it is then established at which angle and over which distance the substrate is displaced in the coordinate system defined by this measuring system, in order to bring the mark P_1 in register with the mark M_1. This not only gives the angular orientation of the image of the line interconnecting the centers of the mask marks M_1 and M_2, that is the angular orientation of the mask MA, but the magnification with which the distance between the marks M_1 and M_2 in the mask is imaged in the substrate plane is then also known. Consequently, it is known with which magnification the mask pattern C is imaged onto the substrate. This information may be employed in order to correct the magnification with which the projection-lens system PL forms an image, for example by adapting the

distance between the mask and the lens system. This adaptation will hardly affect the imaging quality.

Finally, the substrate mark P_2 is moved into the path of the alignment beam b', and, again by means of the system AS_2, the marks P_2 and M_1 are aligned relative to one another. During this alignment the angular orientation of the substrate, that is the angle between the line interconnecting the centers of the marks P_1 and P_2 and the X-direction, is determined. During the alignment of the mark P_2 relative to the mark M_1 the substrate is moved, for example by a combination of a translation and a rotation, so that a possible angular error is eliminated during this alignment. As during the change from position 2 to position 3 the displacement of the substrate is also measured by means of the interferometer system the distance between the substrate marks P_1 and P_2 is also known. During the repeated imaging of the mask pattern C onto the substrate it is then possible to correct for variations in this distance, which variations may be caused for example, by thermal expansion of the substrate of warping of this substrate.